Fire Station 31 Cancer Proportional Incidence Ratio (PIR) Study, 1975 – 2003

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Fire Station 31 Cancer Proportional Incidence Ratio (PIR) Study

Executive Summary

At the request of the Epidemiological Study Advisory Panel, the Washington State Department of Health conducted a proportional incidence ratio (PIR) study of fire department members who were assigned to Fire Station 31 from 1975 – 2003. We compared the distribution of specific types of cancer among the firefighters to the distribution of the same types of cancer in a comparison population consisting of people age 20 and older, living in King, Pierce and Snohomish counties. We adjusted the distributions to account for differences in the ages of the firefighters and people in the comparison population. This study design is a relatively rapid way of identifying potential cancer problems in a population of workers.

A total of 1,622 members of the Seattle Fire Department have worked at Station 31. The study identified 20 different types of cancer in 119 firefighters (approximately 7% of the members) as of December 31, 2003. Of these, six cancers were in females, with the remaining 113 in males. Meaningful analysis could not be carried out for females due to the small number of women with cancer. The following results are for male firefighters.

This study found a 59% excess of prostate cancer and a 57% excess of melanoma of the skin among Station 31 male firefighters relative to the comparison population. The majority of the Station 31 firefighters had been assigned to the station less than 180 hours. The median number of hours worked at Station 31 by firefighters with cancer was 96 hours, which was similar to a median of 116 hours for all Station 31 firefighters.

Although the proportion of all male firefighters with prostate cancer and melanoma of the skin is somewhat higher than would be expected, our finding is consistent with other studies of firefighters. Thus, a finding of excess prostate cancer and melanoma of the skin is not unique to Station 31. Additionally, the diversity of other types of cancer and the relatively short amount of time most firefighters with cancer were assigned to Station 31 argue against a common exposure related to cancer-causing substances in the building.

Recommendations:

1. Based on these findings, we do not recommend further investigation of the association of the physical building and cancer among Station 31 firefighters.

2. Given that Station 31 firefighters may have increased risk of prostate cancer, we recommend that all Station 31 male firefighters discuss the advantages and disadvantages of screening with their physician.

3. Given that Station 31 firefighters may be at high risk for melanoma of the skin, it is particularly important that they are aware of changes in their skin patterns, avoid sun burns and exercise sun protective behaviors when spending time outdoors, such as wearing long sleeved shirts and hats to shade exposed skin.

Background

In October of 2003, the City of Seattle Mayor's Office and the Seattle Fire Department launched an investigation in response to firefighters' concerns that working at Station 31 increased the risk of cancer and other illnesses. Fire Station 31 opened in 1975 and is located in the Northgate area of Seattle.

The overall investigation is comprised of three main components: an industrial hygiene analysis of the Station 31 building and the work of two panels – the Medical Screening Advisory Panel and the Epidemiological Study Advisory Panel. The two panels consist of recognized experts in their relevant fields as well as representatives of the Seattle Fire Department, the Office of the Mayor, Public Health – Seattle & King County (PHSKC) and Firefighters Union Local 27. The Epidemiological Study Advisory Panel's main task was the design and oversight of an epidemiologic study to understand if something in the environment of Station 31 might be causing excess cancer among firefighters assigned to that station. The following is a report of the epidemiologic study.

The objective of the study was to compare the proportional incidence of cancer by primary site among Station 31 firefighters to that of the general population of Snohomish, King, and Pierce counties in order to determine whether cancer patterns in Station 31 members were different from those of the comparison population.

Method

Study Design

This study is a proportional incidence ratio (PIR) analysis of fire department members who were assigned to Fire Station 31 from 1975 – 2003. More specifically, we compared the distribution of specific types of cancer among the firefighters to the distribution of the same types of cancer among persons ages 20 and older, living in King, Pierce and Snohomish counties. We selected this comparison population because the majority of Station 31 firefighters live in these counties and are ages 20 and older. This study design is a relatively rapid way of identifying potential cancer problems in a population of workers. To determine the specific types of cancer, we linked a database containing information for Seattle Fire Department members who had worked at Station 31 at any time since it opened on January 1, 1975, to two cancer databases.

Data Sources

Station 31 Database. City of Seattle personnel used logs and the Computer Automated Dispatch (CAD) system maintained by the Seattle Fire Department and a human resources database maintained by the Executive Administration Department to develop the Station 31 database. They collected work information, including rank, assignment and hours worked from the logs and CAD. The logs were the primary source of work information. CAD, which was implemented in 1992, was used to supplement the logs and as a cross-reference to check for accuracy. City personnel used the human resources database to extract personal information, including social security number, first, middle and last names, date of birth, sex, ethnic group and addresses.

Cancer Registries. Legislation mandates that physicians, health care facilities, surgical centers and laboratories report information on cancer diagnosed among Washington residents to the Washington State Department of Health. The Washington State Department of Health maintains this information in the Washington State Cancer Registry (WSCR). WSCR includes information on all cancers diagnosed except carcinoma in situ of the cervix and non-melanoma skin cancers, such as squamous and basal cell skin cancers. The first year of data in WSCR is 1992. Since 1973, the Fred Hutchinson Cancer Research Center has collected information on cancer among residents of the 13 counties in northwest Washington. Fred Hutchinson Cancer Research Center maintains this information in the Cancer Surveillance System of Western Washington (CSS). Both WSCR and CSS collect information on where the person is living at the time of diagnosis. WSCR has data sharing agreements with other states to obtain information on Washington residents whose cancer is diagnosed or treated out of the state.

Linking Procedures

We first linked the Station 31 database with CSS. To identify firefighters who were diagnosed with cancer outside the area covered by CSS, we also linked the Station 31 database with WSCR. Linking to WSCR allowed us to estimate the number of firefighters with cancer who had moved outside the CSS area, but still lived in Washington. Additionally, since WSCR and CSS used two different methods to link with the Station 31 database, each link served as quality assurance for the other link.

CSS used SQL Server 2000 to link the Station 31 database to their database and performed several passes to maximize the number of matches. The matching fields included first and last names, social security number, and date of birth. The first pass used exact last name, exact first name, and date of birth for the primary match variables with social security numbers to confirm matches. The second pass eliminated records for the matches acquired in the first pass, and used the social security number as the primary match variable, as well as the two name variables and the date of birth to confirm matches. The third pass used date of birth as the primary match variable with the other fields to confirm matches. A report was produced for questionable matches and the CSS personnel manually checked these matches to determine whether they were acceptable. For example, for 'partial' social security number matches the programmer looked at the numbers themselves; if eight of the nine digits were the same or if seven were the same and the other two were transposed, they were considered matches. WSCR used Automatch version 4.2 (MatchWare Technologies, Kennebunk, ME) for the linkage with their cancer database. WSCR used the same matching fields as CSS, as well as a multi-pass process and manual checking.

The CSS linkage included all records that were in CSS as of May 2004. These records are considered at least 95% complete through 2002 and partially complete through 2003. The WSCR link was done in March 2004. These records are considered at least 95% complete through 2001 and partially complete through 2002. Due to the time lag of at least three to nine months between a cancer diagnosis and incorporation into the final database, reports for 2003 are not complete.

Data Analysis

The analytic methods are summarized below. Additional detail is available in the Technical Appendix.

PIRs were calculated for each type of cancer diagnosed among the firefighters using the analytical plan agreed upon by the Epidemiological Study Advisory Panel. In short, we compared the distribution of specific types of cancer in the firefighters to the distribution that would be expected if the patterns in the firefighters were the same as those in the comparison group. The comparison group was the population ages 20 and older of King, Pierce and Snohomish counties. The PIRs were also adjusted to account for the different age structures of the two groups. A PIR of 100 indicates that the observed number of firefighters with a particular cancer was equal to the expected number. A PIR of 50 means that the number of firefighters with a specific type of cancer was half of that expected and a PIR of 200 indicates that the number of firefighters with cancer was twice the expected number.

We calculated PIRs separately for men and women. We also calculated PIRs for a subset of men who were assigned to Station 31 for more than 180 hours, approximately one month. This represented approximately 50% of the male firefighters assigned to Station 31. Hours assigned were calculated by adding the number of hours for each shift. Being assigned to Station 31 is not equivalent to spending time in the building, since firefighters are frequently away from their assigned station for a large part of their work time.

To assess the precision of the PIRs, two-sided 95 percent confidence intervals (95% CI) were calculated using the Poisson distribution. A confidence interval is a range of values that is normally used to describe the uncertainty around an estimate and it measures the variability in the data. With a 95% CI, there is a 95% chance that the confidence interval covers the true value of the PIR. Since we are comparing the age-adjusted PIRs for specific types of cancers to a standard value of 100, the confidence intervals are equivalent to statistical tests. If the 95% CI for a PIR includes 100, then the proportion of firefighters with that cancer is not statistically significantly different from the proportion of the general population with the same cancer.

Results

The CSS linkage identified 115 firefighters with cancer. There were exact matches in all fields for 99 individuals, whereas 16 individuals slightly differed in one of the four matching fields (e.g., one number in the social security number was transposed or the last name in one of the databases included a suffix such as Jr.). The WSCR linkage identified 59 firefighters with cancer, 55 of whom were also identified in CSS. The remaining four firefighters had moved from the CSS area, but still lived in Washington when they were diagnosed. After the addition of the four individuals diagnosed outside the CSS area, there were a total of 119 Station 31 firefighters with cancer diagnosis between 1975 and 2003. The WSCR linkage did not identify any omissions in the CSS linkage. One person was identified by CSS and should have been identified by WSCR, but was not.

Demographic characteristics of Station 31 firefighters, firefighters with cancer and the three-county comparison population are presented in Table 1. Because of the small number of female firefighters with cancer (reflecting the small number of females assigned to Station 31), information on race, county, age and age at diagnosis are for the male population only. The ages for the male Station 31 firefighters (i.e. those in column two includes firefighters both with and without cancer) were determined by calculating their age on April 01, 2000.

Most of the firefighters are men and the proportion of men and women firefighters diagnosed with cancer is the same as their proportions in the Station 31 workforce. The distribution of men and women at Station 31 is very different from that of the comparison

Table 1. Demographic details for Station 31 firefighters, firefighters with cancer and the comparison population

Characteristics	Station 31 Firefighters (%) N=1,622	Number of Firefighters w/Cancer (%) N=119	Comparison Population w/Cancer (%) N= 154,704
Sex			
Males	1,532 (94%)	113 (95%)	154,704 (47%)
Females	90 (6%)	6 (5%)	177,640 (53%)
Race§			
Caucasian	1,311 (86%)	101 (89%)	141,342 (91%)
African-American	125 (8%)	8 (7%)	5,838 (4%)
Asian	67 (4%)	2 (2%)	4,655 (3%)
Other	29 (2%)	2 (2%)	2,869 (2%)
County§			
King	693 (45%)	71 (63%)	92,414 (60%)
Pierce	140 (9%)	3 (3%)	35,804 (23%)
Snohomish	354 (23%)	30 (27%)	26,486 (17%)
Other	345 (23%)	9 (7%)	N/A
Age or age at diagnosis (years)§			
20-29	145 (9%)	2 (2%)	2,793 (2%)
30-39	332 (22%)	7 (6%)	5,846 (4%)
40-49	308 (20%)	18 (16%)	10,656 (7%)
50-59	532 (35%)	48 (42%)	24,506 (16%)
60-69	162 (11%)	29 (26%)	43,460 (28%)
70-79	49 (3%)	7 (6%)	45,454 (29%)
80 +	3 (<1%)	2 (2%)	21,989 (14%)

§Demographic characteristics of race, county and ages at diagnosis are for the male population only. The age distribution for all male Station 31 firefighters (N = 1,532) was determined by calculating their age on April 01, 2000.

population and so we analyzed cancer data for men and women separately. The racial distribution of firefighters with cancer is the same as the racial distribution of the Station 31 workforce and similar to that of the comparison population.

The firefighters were diagnosed with cancer at younger ages than the comparison population. This is, in part, a reflection of a relatively young workforce at Station 31 that has not had the time to age into the older age groups. Table 1 shows that in 2000 35% of firefighters who had ever been assigned to Station 31 were ages 50 – 59 and 11% were ages 60 – 69. Less than 4% were ages 70 and older. This means that in 1990, less than 4% were ages 60 and older and in 1980, less than 4% were 50 and older. In contrast, the comparison population in 1990 had a much higher proportion of people in the older age groups; 17% were ages 60 and older. Thus, with few firefighters in the older age groups, it is not surprising that a larger proportion of Station 31 firefighters were diagnosed in their 50s compared to the comparison population. Additional reasons for the relatively younger age at diagnosis are tied to specific types of cancer and discussed in the Discussion section.

Table 2. Age-adjusted proportional incidence ratios (PIRs) for selected cancers in Station 31 male firefighters, 1975 – 2003

Site	Observed	Expected	PIR§	95% Confidence Interval§
Bladder	7	6.3	111	45-229
Brain	<3	2.5		
Colorectal	12	12.3	97	50-170
Esophagus	<3	1.5		
Eye	<3	0.4		
Heart, Mediastinum and Pleura	<3	0.5		
Kidney and renal pelvis	3	3.8	79	16 -230
Larynx	<3	2		
Leukemia	6	4.7	127	46-275
Lung and Bronchus	8	17	45	20-89*
Lymph Nodes	4	4.9	81	22-207
Melanoma of the skin	18	10.8	167	99-264
Oral cavity and Pharynx	3	5.3	57	12-167
Pancreas	<3	2.3		
Prostate	37	23	159	112-220*
Retroperitoneum and Peritoneum	<3	0.2		
Soft tissues	3	0.9	349	72-1019
Stomach	<3	2.4		
Testis	<3	2.7		
Thyroid and endocrine glands	<3	1.3		

* Statistically significant at p=.05 level

§ To protect confidentiality observed numbers, PIRs and 95% CI for types of cancer diagnosed in fewer than three firefighters are not presented. None of those PIRs was statistically significant.

Table 2 shows the types of cancer diagnosed among the Station 31 male firefighters, the number of firefighters with each type of cancer (observed), the number of firefighters who would be expected to have a specific type of cancer if the distribution among the firefighters was the same as in the comparison population (expected), the age-adjusted PIRs and the 95% confidence intervals. To protect confidentiality, the PIRs and 95% confidence intervals are not provided for types of cancer that were diagnosed in fewer than three firefighters. However, none of those PIRs was statistically significant.

There is a diversity of types of cancer in Station 31 firefighters, representing 20 different cancer "sites." A cancer site is the place in the body where the cancer originates. For most cancers, more than one type of cancer can be diagnosed at each site. For example, leukemia is a cancer of blood cells, but within that general category, there are several types of leukemia each of which may have its own unique causes. A statistically significant excess is observed for prostate cancer (PIR=159, 95% CI 112 – 220) and a statistically significant deficit is found for cancer of the lung and bronchus (PIR=45, 95% CI 20 – 89). An excess of melanoma of the skin is also observed, but this does not quite reach statistical significance (PIR=167, 95% CI 99 – 264). Exclusion of the four firefighters diagnosed outside of the CSS region does not significantly change the results.

Table 3 shows the same information as Table 2 for male firefighters who were assigned to Station 31 for at least 180 hours (approximately 1 month) during 1975 – 2003. There are 13 types of cancer among 41 firefighters. The excess of prostate cancer persists (PIR=191, 95% CI 107-315). The lowered proportional incidence of cancers of the lung and bronchus continues, but is no longer statistically significant. Melanoma of the skin remains elevated, but not statistically significant.

Table 3. Age-adjusted proportional incidence ratios (PIRs) for selected cancers in male firefighters assigned to Station 31 for at least 180 hours, 1975-2003

Site	Observed	Expected	PIR§	95% Confidence Interval§
Bladder	<3	2.2		
Brain	<3	1.0		
Colorectal	3	4.4	68	14-198
Esophagus	<3	0.6		
Heart, Mediastinum and Pleura	<3	0.2		
Leukemia	<3	1.7		
Lung and Bronchus	3	6.3	48	10-139
Lymph Nodes	<3	1.9		
Melanoma of the skin	9	4.1	217	99-412
Pancreas	<3	0.8		
Prostate	15	7.9	191	107-315*
Retroperitoneum and Peritoneum	<3	0.1		
Soft tissues	<3	0.3		

* Statistically significant at p=.05 level

§ To protect confidentiality observed numbers, PIRs and 95% CI for types of cancer diagnosed in fewer than three firefighters are not presented. None of those PIRs was statistically significant.

Table 4. Breakdown for male firefighters who have been assigned to Station 31 for 1, 5 and 10 years or more and percent with cancer

Time assigned	Number of male firefighters	Number of male firefighters w/cancer	% of firefighters with cancer
1 year or more	237	17	7%
5 years or more	64	6	9%
10 year or more	25	2	8%

* Firefighters assigned to Station 31 for 5 and 10 years or more are a subset of the firefighters who were assigned for one year or more.

Because most cancers take years to develop, we wanted to assess cancer among firefighters who had been assigned to Station 31 long term. However, this assessment was not possible due to the relatively small number of cancers and the diversity in cancer types diagnosed in men who had been assigned to Station 31 for a year or more. Table 4 presents information for male firefighters who were assigned to the station for one year or more (2,160 hours), five years or more (10,800 hours) and 10 years or more (21,600 hours). Of the 237 male firefighters who had been assigned to Station 31 one year or more, 17 developed cancer. Seven of these men had prostate cancer and the remaining 10 had nine different types of cancer, including cancers of the bladder, brain, colorectal, esophagus, lung, pancreas, prostate, leukemia and melanoma of the skin. There were 64 male firefighters (a subset of the firefighters who were assigned to the station one year or more) assigned to Station 31 for five years or more, six of whom developed five different types of cancer. Of the 25 firefighters assigned for ten years or more, two developed different types of cancer. Meaningful statistical analysis could not be performed, given that no one type of cancer occurred more than twice, except for prostate cancer among men who had been assigned to Station 31 for at least a year. The higher proportional incidence of prostate cancer in Station 31 firefighters has already been established, so further analysis will not affect the study results. It is interesting to note that the proportion of men with cancer is similar in all three groups. If a contaminant at Station 31 was causing cancer, we would expect that the proportion of men with cancer would be highest among those assigned the longest.

Figure 1 provides additional evidence that the time assigned to Station 31 is not related to the development of cancer. Figure 1 presents the amount of time assigned to Station 31 for all male firefighters, firefighters with prostate cancer and firefighters with melanoma of the skin. Similar patterns are seen for all three groups, although those with melanoma have a somewhat larger percent in the 1 – 12 month group. This is because a large proportion of firefighters with melanoma had been assigned to the station for one to three months. About 50% – 60% of firefighters in each of these groups had been assigned to Station 31 for less than one month (less than180 hours) and about 10% – 20% had been assigned for a year or more. The median number of hours worked at Station 31 by firefighters with cancer was 96 hours (ranging from 10 – 29,286 hours). This is similar to a median of 116 for all Station 31 male firefighters, regardless of whether they had cancer.

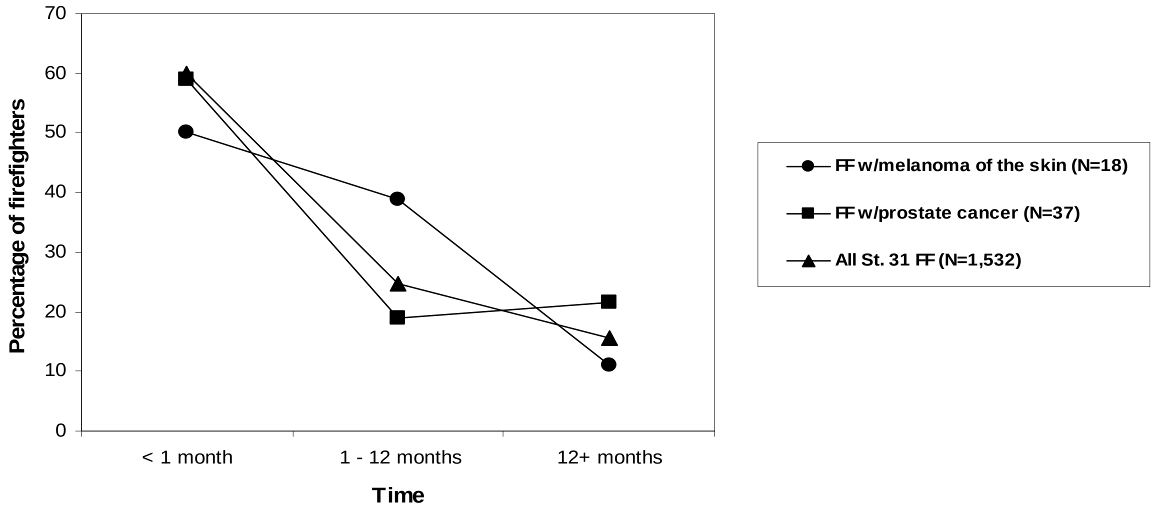

Figure 1. Time assigned to Station 31, Males

For prostate cancer and melanoma of the skin, we investigated whether the year of diagnosis or the year of first employment at Station 31 affected the PIRs. PIRs were calculated by decades (1975–1984, 1985–1994 and 1995–2003) for prostate cancer and melanoma of the skin separately. The PIRs did not differ significantly from the original analysis. Therefore, we concluded that there was little or no influence on the outcome by year of diagnosis or by year of first employment.

There were five types of cancer among the six female firefighters. These included cancers of the breast, uterus, cervix, oral cavity and pharynx, and melanoma of the skin. No meaningful statistical analysis could be performed given that no specific type of cancer occurred more than twice.

Discussion

The association between firefighting and health outcomes, particularly cancer, has been widely studied, since firefighters may be exposed to a variety of carcinogens while on the job. Unfortunately, findings from the cancer studies have not been consistent. The outcomes of most of these studies have been well summarized in three reviews.

In 1990, Howe and Burc reviewed the evidence for several types of cancer that had been reported in epidemiologic studies as being associated with firefighting (1). These cancers included lung cancer, colon cancer, brain tumors, melanoma of the skin and multiple myeloma. The review concluded that the evidence for a positive association was strongest for brain tumors and multiple myeloma, with some association for melanoma of the skin. There was no evidence of an association with lung or colon cancers.

In another review, Guidotti examined the evidence for occupational mortality among firefighters and included cancers at selected sites (2). The review did not include prostate cancer. He concluded that there was strong evidence for an association between firefighting as an occupation and mortality from genitoururinary cancer, including that of the kidney, ureter and bladder. He also found some evidence supporting associations with mortality from cancers of the lung, brain, colon and rectum, and leukemias and lymphomas.

In a more recent review, Haas and colleagues explored mortality patterns in firefighters in relation to their duration of employment (3). The review included only mortality studies that used standardized mortality ratios. The authors looked at deaths due to all causes, coronary artery disease, cancer (all cancers combined, lung cancer and brain cancer) and respiratory disease. They found no consistent evidence that employment as a firefighter or time employed was associated with increased mortality from any of the causes studied.

The Washington State Occupational Mortality Database is an interactive website that displays the proportional mortality ratios (PMRs) using deaths occurring in Washington State residents between 1950 and 1999 (4). A PMR is similar to a PIR, except that it looks at the proportional distribution of deaths, rather than incidence. In this database, deaths are grouped into occupation and cause-of-death categories for which PMRs are computed. Information from this database shows Washington State male firefighters at significantly higher risk for mortality from leukemias and lymphomas (PMR = 132, 95% CI 106,163) and melanoma of the skin (PMR = 228, 95% CI 132,363). There was no indication that firefighting as an occupation increased the risk for mortality from prostate cancer (PMR = 109, 95% CI 87,135).

It is not surprising that the findings for prostate cancer mortality differ from those in the current study that looked at incidence. Survival for men with prostate cancer is good. According to the American Cancer Society, about one in six men will be diagnosed with prostate cancer at some point in their lives, but only one man in 33 will die of this disease (5). Second, as discussed in more detail below, screening for prostate cancer affects incidence, but not mortality (6,7), and it is likely that part of the excess of prostate cancer among Station 31 firefighters is related to screening practices.

The current analysis found an excess of prostate cancer that continued to be statistically significant among firefighters who worked more than 180 hours at Station 31. This finding is consistent with studies of Baris et al. (8) and Demers et al. (9). Although Baris and colleagues did not find an excess of prostate cancer mortality in Philadelphia firefighters, they did find a subset of firefighters with less than 10 years of employment to be more than twice as likely to die of prostate cancer when compared to U.S. white men. Similarly, Demers and colleagues observed a 40% elevated risk of prostate cancer in a cohort of 2,447 male firefighters in the Seattle and Tacoma area relative to the general population. The elevation was not found relative to rates in policemen.

The role of screening needs to be considered in understanding the excess of prostate cancer among Station 31 firefighters and their relatively younger ages of diagnosis. The mean age at diagnosis for firefighters with prostate cancer was 60 years old compared to 70 years old for the comparison population. Many prostate cancers grow very slowly and so in the absence of screening, men either die of other causes without the prostate cancer ever being detected or it is detected later in life when symptoms of the disease arise. In well-screened populations, however, these cancers are detected before symptoms arise. Thus, screening has the effect of increasing the number of men diagnosed with prostate cancer and lowering the age at diagnosis.

There are two indications that Station 31 firefighters might be screened for prostate cancer more frequently than the comparison population. First, men with health insurance are more likely to be screened for prostate cancer compared to men without health insurance (10). Unlike men in the comparison population, who may or may not have health insurance, all firefighters are insured. Second, the goal of screening is to find cancer at a relatively early stage in its development. Stage at diagnosis indicates whether the cancer has spread at the time it is diagnosed, and if so, how extensively. Early stage (technically called, in situ and local) means that the cancer has not spread to other parts of the body. We used WSCR data from 1992 through 2002 to assess stage at diagnosis for Station 31 firefighters with prostate cancer (19 of the 37 firefighters with prostate cancer were diagnosed within this time period) and for the comparison population. We used WSCR, because we had timely access to the database and because screening was more common in the 1990s than earlier. Approximately 80% of firefighters were diagnosed at an early stage compared to approximately 70% in the comparison population. While this was not statistically significant, it suggests that a higher proportion of firefighters were diagnosed at earlier stages than the comparison population, perhaps as a reflection of screening.

Although the PIR for melanoma of the skin in the current study did not reach statistical significance, several studies observed an elevated risk in firefighters for melanoma of the skin (11-13). For example, a proportionate mortality study of firefighters in New Jersey found a statistically significant elevation in melanoma, with a PMR of 148 when compared to the state's general population, but no elevation when police officers were used as the reference population (12).

We observed a significant deficit in lung and bronchus cancer among Station 31 firefighters, but this was not significant when including only firefighters who had been assigned to Station 31 for 180 hours or more. This, as well as finding no significant elevations or deficits for other types of cancer, may be related to our inability to detect deficits and excesses for cancers that are diagnosed in relatively few firefighters. With relatively few diagnoses, we have wide confidence intervals making it difficult to conclude definitely that there are no deficits or excesses. This limitation especially affects our ability to find relatively small deficits or excesses.

In addition to being statistically limited by a small number of diagnoses for some types of cancer, there are several limitations that affect our ability to interpret our findings. A major limitation of PIR studies is that they do not estimate the *overall* cancer rate. Without an estimate of the overall cancer rate, PIRs may be misleading. Thus, a PIR for a specific type of cancer may appear to be elevated even if the overall cancer rate in firefighters is low. Conversely, PIRs can appear to be low even if the overall cancer rate is high. This limitation may be easiest to conceptualize as pies sliced into the same or different numbers of portions. With a PIR, we only know the relative size of portions in each pie. We can tell, for example, whether both pies are cut into eight equal sized slices or whether one pie has eight equal sized slices and the other has one huge slice and seven small slices. We do not know anything about the size of the pies.

A second limitation of PIR studies is that data reflect the proportional distribution of cancers in a population. Thus, an excess of one type of cancer lowers the PIR of all the other cancers by an unknown amount. Likewise a deficit for one type of cancer would raise all the other PIRs by an unknown amount. To continue the pie analogy, if one person takes an extra large slice (representing an excess of one specific type of cancer), everyone else will get less. Likewise, if the first person takes a teeny piece, there is more to be shared among everyone else.

Due to these limitations, PIR studies are not definitive. They are useful as tools to determine whether additional investigation is warranted.

Given the good correspondence between the linkage of CSS and WSCR data with the firefighters database, we are confident that we did not miss firefighters who were diagnosed in the time periods and geographic areas covered by the cancer registries. There were 84 firefighters (approximately 5% of Station 31 members) with an out of state address. Three of the 84 firefighters were matched to the cancer registry, meaning that they were diagnosed with cancer before they moved out of the state. We do not know how many of the remaining 81 firefighters may have left Washington State and subsequently been diagnosed with cancer elsewhere. Thus, we may have missed an unknown number of the firefighters diagnosed with cancer. However, the same issue exists for the comparison population; people who had lived in the three-county area and then left the area prior to a diagnosis of cancer are not included. Additionally, because we looked at the distribution of specific types of cancer relative to all cancers, for our results to change significantly, missing cancer diagnoses would have to include a large proportion of the same type of cancer.

As another quality assurance step, we compared a list of 33 firefighters reported to have cancer, provided by Station 31, to the list of firefighters with cancer used in the current study. We confirmed that all the firefighters on the list were included in the Station 31 database, but found that 13 were not in the cancer database used for the PIR analysis. We contacted five of these 13 firefighters for additional information. We found that two of the people did not have cancer, two had non-melanoma skin cancers (which are not included in the cancer registries), and one person had been diagnosed with cancer in 2003. CSS confirmed that the person diagnosed in 2003 was not included because of the time lag between diagnosis and incorporation into the database. Since the information from these five firefighters did not affect our results, we did not follow up with the remaining firefighters.

Recommendations

Based on these findings, we do not recommend further investigation of the association of the physical building and cancer among Station 31 firefighters. This study showed a statistically significant excess only for prostate cancer, a finding that is consistent with another study of cancer incidence among firefighters in the Seattle and Tacoma area and not unique to Station 31. The diversity of other types of cancer and the relatively short amount of time most firefighters with cancer were assigned to Station 31 (median of 96 hours) argue against a common exposure related to the Station 31 building. Additionally, the cause of prostate cancer is currently unknown. When there are relatively few people with a specific type of cancer and when there is no obvious environmental exposure, a special study is unlikely to shed light on the cause of cancer.

Given that firefighters at Station 31 might have increased risk of prostate cancer, we recommend that all Station 31 male firefighters discuss the advantages and disadvantages of screening with their physician. Among men in Washington and nationally, prostate cancer is the most common cancer and the second leading cause of cancer death (14). Although the causes of prostate cancer are not well understood, researchers have found several risk factors that increase the risk of developing the disease: high-fat diets, increasing age, African-American race and a positive family history of prostate cancer (15). Major scientific organizations currently differ on their recommendations for prostate cancer screening. Thus, the Washington State Department of Health recommends that firefighters speak with their medical provider about what is appropriate for them.

Unlike prostate cancer, risk factors for melanoma of the skin are widely established. They include increasing age, Caucasian race, sunburns, moles and ultraviolet radiation exposures (16). Given that Station 31 firefighters might be at high risk of melanoma, it is particularly important that they are aware of changes in their skin patterns and avoid sun burns. The Centers for Disease Control and Prevention (CDC) promotes exercising sun protective behaviors when spending time outdoors, such as wearing long sleeved shirts and hats to shade exposed skin. The American Cancer Society recommends monthly self-examination that includes looking for changes in moles or other marks on the skin, especially those that possess one or more of the following characteristics: asymmetry (that is, one side does not match the other), have irregular borders (that is, the edges of the mole are raged or notched), have more than one color or shade, or are larger than about ¼ inch across (16). These guidelines can be easily remembered as A (**a**symmetrical), B (irregular **b**orders), C (more than one **c**olor) and D (**d**iameter greater than ¼ inch).

Glossary of Terms

Age-adjustment: a process of accounting for the effect of age because it is associated with many diseases and exposures. Age-adjustment is often performed to eliminate differences in observed rates that result from age differences in the population composition. This is particularly important in age-related diseases, such as cancer.

Carcinogen: substance or agent that produces cancer

Comparison population: a group to which the index group is compared. In this study the main index group is the firefighters with cancer and the comparison population is the population of King, Pierce and Snohomish counties.

Demographic: descriptive information on a population

Distribution: a summary of the number (frequency) of occurrences. May be based on experimental data or may be theoretical in nature.

Epidemiology: the study of the occurrence of disease or other health-related events in human populations, and the application of this study to control health problems.

Expected number: age-adjusted number of cancers in firefighters that would have occurred, if the patterns in the firefighters were the same as those in King, Pierce and Snohomish counties.

Median: a middle value in the data set that divides a distribution exactly in half. It is also referred to as the 50th percentile and not excessively influenced by extreme values.

Observed number: the actual number of firefighters with cancer

Proportion: the number of observations with certain characteristics divided by the total number of observations; usually presented as a fraction to show the magnitude of one quantity to the magnitude of another.

Proportional incidence ratio (PIR): the proportion of observed incidences from a specified condition in a defined population, divided by the proportion of expected incidences from this condition in a standard population.

Proportional mortality ratio (PMR): the proportion of observed death from a specified condition in a defined population, divided by the proportion of expected deaths from this condition in a standard population.

Poisson distribution: a probability distribution used to model the occurrence of a rare event.

Risk factors: attributes or exposures that increase the chances of occurrence of diseases or other outcomes.

Statistical significance: indicates that the result is not likely due to chance. It is customary to designate a 95% significance level, meaning that there is a 5% chance that the result was from chance alone.

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Technical Appendix

Site-specific proportional incidence ratios (PIRs) adjusted for age were calculated by dividing the observed number of site-specific cancer in firefighters (O_i) by the expected number (E_i). The expected number of cases for each cancer site was obtained by using the number of site-specific cancers in the referent group (P_i), multiplied by the ratio of total cancer cases in firefighters (S_i) to total cancer cases in the referent cohort (T_i). The observed and expected numbers were then summed across a 10-year age strata for each cancer type.

To compute PIRs, cancer cases were tabulated in the following typical table for specific cancer site group:

	Site specific cancer	All cancers
Firefighters	O_i	S_i
Referent Group	P_i	T_i

where,

i = age group
O_i = observed cases in firefighters due to specific cancer
P_i = total cases in referent group due to specific cancer
S_i = total cancer cases in firefighters
T_i = total cancer cases in the referent group

then,

$E_i = (P_i)\frac{S_i}{T_i}$ = the expected number of case in referent group due to specific cancer.

$$PIR = \frac{\sum_{i=1}^{n} O_i}{\sum_{i=1}^{n} E_i} \times 100$$

Results of this study are reported as PIRs; the number of observed site-specific cancer divided by the number of expected site-specific cancer (using the general male population of King, Pierce and Snohomish counties) multiplied by 100.

Two-sided 95 percent confidence intervals were calculated for all PIRs using the Poisson distribution. The Poisson distribution is a discrete distribution which takes on a value of x=0,1,2,3,… and is often used as a model for the number of rare events in a specific time period. For studies with observed cases less than 100, it is recommended that the confidence intervals be calculated directly from this distribution. This is done by obtaining the upper limit (UL) and lower limit (LL) for the confidence interval for the observed number of cases and then using a standard formula for obtaining the confidence interval for the PIR. The standard formula is given by

LowerLimit = (LL/E) (100)

UpperLimit = (UL/E) (100)

The upper and lower limits for the observed numbers were taken from the following table:

Table 1: Poisson distribution 95% confidence limits.

Observed	Lower Limit	Upper Limit		Observed	Lower Limit	Upper Limit
0	0.0000	2.9957		20	12.2165	30.8884
1	0.0253	5.5716		21	12.9993	32.1007
2	0.2422	7.2247		22	13.7873	33.3083
3	0.6187	8.7673		23	14.5800	34.5113
4	1.0899	10.2416		24	15.3773	35.7101
5	1.6235	11.6683		25	16.1787	36.9049
6	2.2019	13.0595		26	16.9841	38.0960
7	2.8144	14.4227		27	17.7932	39.2836
8	3.4538	15.7632		28	18.6058	40.4678
9	4.1154	17.0848		29	19.4218	41.6488
10	4.7954	18.3904		30	20.2409	42.8269
11	5.4912	19.6820		31	21.0630	44.0020
12	6.2006	20.9616		32	21.8880	45.1745
13	6.9220	22.2304		33	22.7157	46.3443
14	7.6539	23.4896		34	23.5460	47.5116
15	8.3954	24.7402		35	24.3788	48.6765
16	9.1454	25.9830		36	25.2140	49.8392
17	9.9031	27.2186		37	26.0514	50.9996
18	10.6679	28.4478		38	26.8911	52.1580
19	11.4392	29.6709		39	27.7328	53.3143